

Horn Mountain Offshore Oil Field Case Study

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ACRONYMS AND ABBREVIATIONS

ϕ	Reservoir porosity	MESA	Mission Execution and Strategic Analysis
A	Accessible oil area	mi	Mile
API	American Petroleum Institute	MM	Million
ARI	Advanced Resources International	MMbbl(s)	Million barrels
atm	Atmosphere	MMcfd	Millions of cubic feet per day
Ave Pres	Average pressure for pore volume per sector	MW	Molecular weight
B/AF	Barrels per acre foot	NETL	National Energy Technology Laboratory
bbl	Barrel	NFB	North Fault Block
bbl/d	Barrel per day	OCS	Outer Continental Shelf
Bcf	Billion cubic feet	OOIP	Original oil in place
Boi	Initial oil formation volume factor	Pc	Critical pressure
CFB	Central Fault Block	psi	Pounds per square inch
cfd	Cubic feet per day	psia	Pound per square inch absolute
CO ₂	Carbon dioxide	SC	Standard conditions
Cum	Cumulative	scf	Standard cubic foot
DOE	Department of Energy	Sg	gas saturation
DP	Dykstra-Parsons	Sim	Simulated
EFB	East Fault Block	Soi	Initial oil saturation
EOR	Enhanced oil recovery	Sor	Residual oil saturation
F	Net pay	Sw	Water saturation
ft	Foot	Swi	Initial water saturation
GOM	Gulf of Mexico	Tc	Critical temperature
K	Kelvin	TVDSS	True vertical depth below sea surface
Kr	Relative permeability	U.S.	United States
Krg	Gas relative permeability	°F	Degrees Fahrenheit
Krog	Oil relative permeability for gas-oil system		
Krow	Oil relative permeability for water-oil system		
Krw	Water relative permeability		
Mcf	Thousand cubic feet		
mD	Millidarcy		

1 INTRODUCTION

Offshore Gulf of Mexico (GOM) outer continental shelf (OCS) oil fields offer significant potential for storage of carbon dioxide (CO₂) emissions and incremental production of oil using CO₂ enhanced oil recovery (EOR). The National Energy Technology Laboratory (NETL) has developed a robust set of onshore CO₂ EOR modeling tools (e.g., the Fossil Energy/NETL CO₂ Prophet Model [CO₂ Prophet Model]), [1] [2] which may be adaptable for modeling offshore CO₂ EOR potential. However, rigorous evaluation of CO₂ storage and CO₂ EOR in the offshore also requires information on offshore reservoir characteristics, existing oil field infrastructure, and other key features.

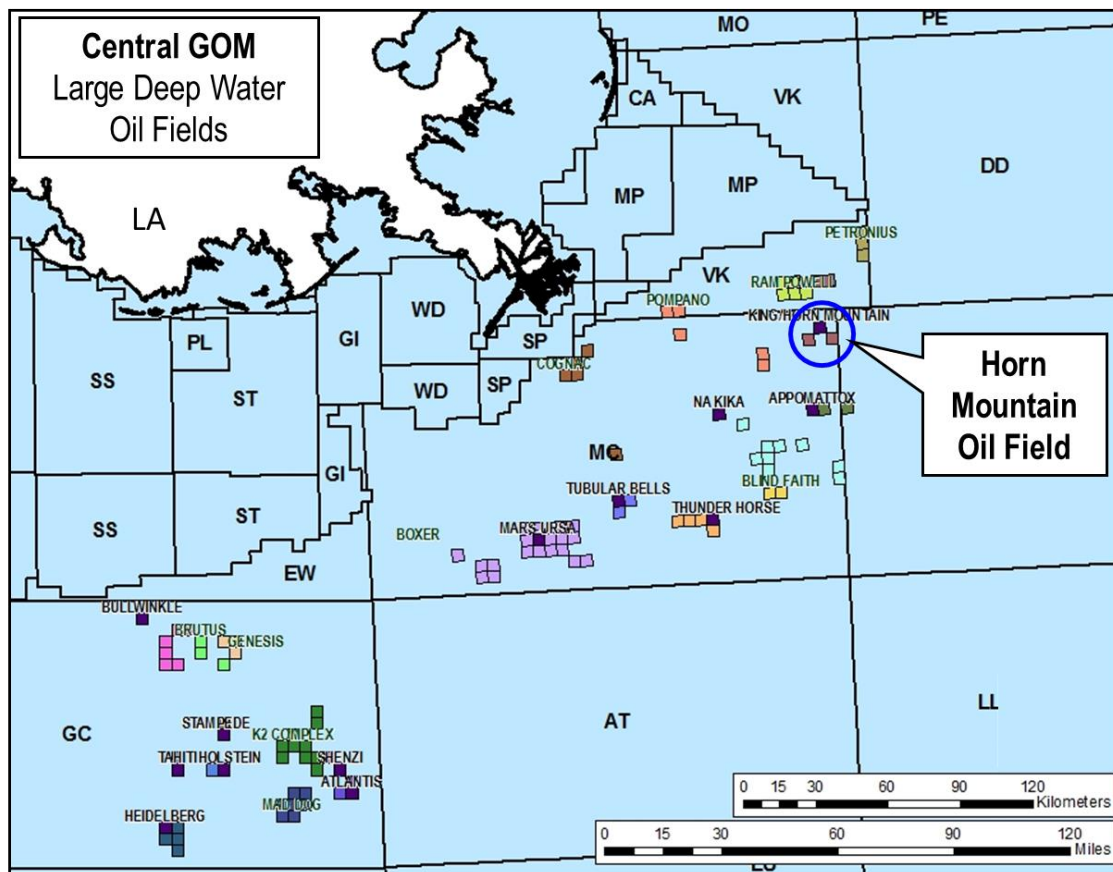
A subset of GOM OCS offshore oil fields were investigated to identify three case studies -- Horn Mountain oil field (discussed in this report), Cognac oil field, [3] and Petronius oil field [4] --that would help generate an initial body of knowledge on the challenges of evaluating the potential of offshore CO₂ EOR and CO₂ storage. A primary purpose of these case studies was to assess to what extent the CO₂ Prophet Model can reasonably represent the performance of an offshore CO₂ flood, including capturing the geologic complexity and irregular well spacings typical of offshore oil fields. To perform the assessment of the capabilities of the CO₂ Prophet Model, the following seven tasks were completed:

1. Built a representative geologic model for the Horn Mountain oil North Fault Block (NFB) M Sand including capturing its structural setting and associated aquifer
2. Assembled the key reservoir properties of the NFB M Sand, including its volumetric data, fluid flow capabilities (including relative permeability curves), and oil composition to construct a reservoir model
3. Established the locations of the existing oil/gas production wells and water injection wells in the NFB M Sand
4. Used Computer Modelling Group Ltd.'s GEM compositional simulator ("GEM") to provide a "first-order" history match of fluid production from the NFB M Sand and to calibrate the NFB M Sand's geologic and reservoir description with its oil, gas, and water production history
5. Appraised the performance of a post-waterflood CO₂ EOR project in the NFB M Sand using GEM with a calibrated geologic/reservoir description
6. Appraised the performance of a post-waterflood CO₂ EOR project in the NFB M Sand using the CO₂ Prophet Model (a variant of the NETL CO₂ Prophet Model with similar functionality and performance analysis) in parallel with GEM
7. Compared the modeling results of a post-waterflood CO₂ EOR project in the Horn Mountain oil field NFB M Sand from GEM and the CO₂ Prophet Model to determine whether the CO₂ Prophet Model could reasonably represent the performance of the CO₂ flood compared to the more sophisticated GEM

2 HORN MOUNTAIN OIL FIELD

The Horn Mountain oil field (MC126/MC127) is located in Central GOM, approximately 80 miles from onshore Louisiana (Exhibit 2-1). [5] Horn Mountain, while located in 4,500 feet of water depth, has a structurally complex reservoir setting, analogous to shallow water Central GOM oil fields. As such, this field provides a representative geologic setting for appraising the potential of conducting CO₂ EOR in both shallow and deep-water oil fields. Horn Mountain oil field, with 138 million (MM) barrels (bbl) of original oil reserves and 127 billion cubic feet (Bcf) of original gas reserves, has produced over 85 percent of its original oil and gas reserves, as of the end of 2017. Oil production, that peaked at over 58,000 bbl per day (bbl/d) in 2003, has declined to 12,500 bbl/d in 2018. This implies that Horn Mountain oil field will be depleted within five to ten years, making it a priority candidate for EOR using injection of CO₂.

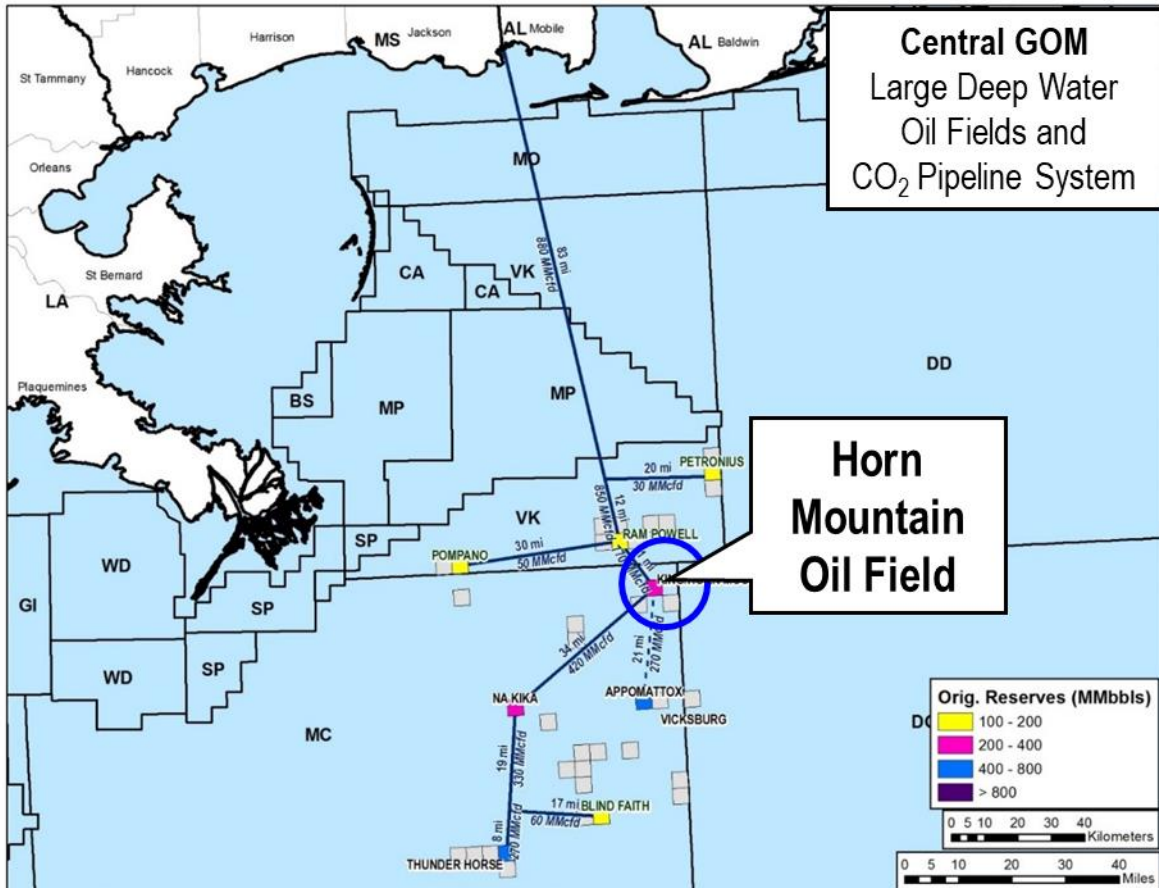
Exhibit 2-1. Location of Horn Mountain oil field, Central GOM



Horn Mountain oil field was developed using a free-floating truss spar, the largest of its kind in the world at the time, measuring 580 feet (ft) high and 110 ft in diameter, with space for 14 wells. After appraisal drilling, eight production wells and two water injection wells were drilled in 2001–2003. With concerns about the strength of the aquifer underlying the oil field, the operator initiated a waterflood in 2003 that lasted until 2011.

As part of an initial review of the potential of offshore CO₂ EOR, Exhibit 2-2 illustrates how a regional offshore CO₂ pipeline system could connect the Horn Mountain oil field and other offshore oil fields to CO₂ supplies from onshore Alabama and Mississippi. [5]

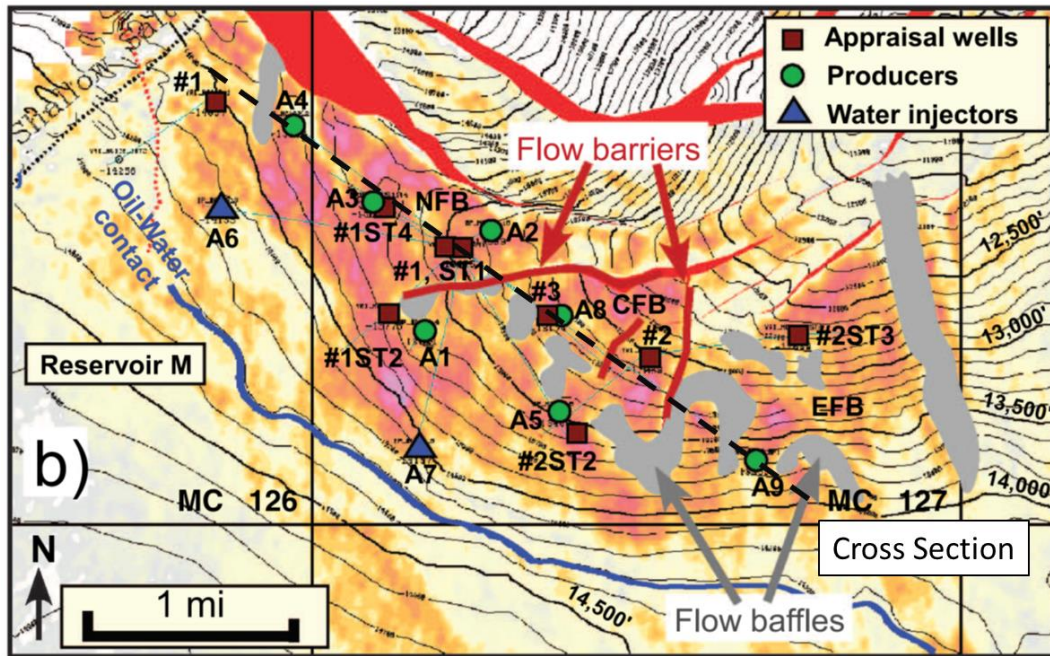
Exhibit 2-2. Potential CO₂ pipeline system for Horn Mountain oil field, Central GOM



2.1 STRUCTURAL SETTING

The Horn Mountain oil field includes two stacked Middle Miocene sands (reservoirs)-- the J Sand and the M Sand. The reservoirs dip to the southwest and are bounded by several large structural faults. These faults divide the field into three distinct production areas-- North Fault Block (NFB), Central Fault Block (CFB), and East Fault Block (EFB) (Exhibit 2-3).

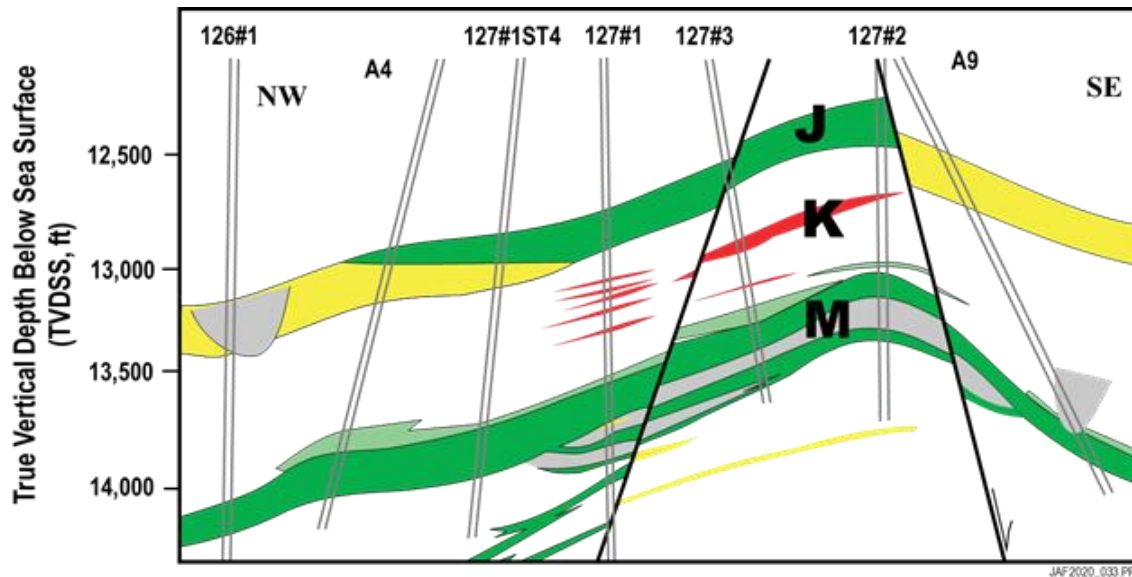
Exhibit 2-3. Horn Mountain M Sand well locations, structural features, and fault blocks



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The northwest to southeast cross-section for Horn Mountain shows the oil bearing (green) portions of the J Sand and the M Sand, separated by a thin gas bearing (red) K Sand (Exhibit 2-4, data from Milkov [6]). The M Sand is layered with internal shale sequences (gray), particularly in the CFB and EFB. In the NFB, the M Sand is a relatively uniform anticlinal structure with bounding faults on the north and east.

Exhibit 2-4. Horn Mountain J Sand and M Sand and well locations



2.2 HORN MOUNTAIN OIL RESOURCES

The M Sand, the largest sand in the Horn Mountain oil field, has 367 MMbbls of original oil in place (OOIP) and an expected recovery efficiency of about 33 percent (after waterflooding) making it an attractive candidate for CO₂ EOR, (Exhibit 2-5). [5] The J Sand has OOIP of 40 MMbbls and is too small for a stand-alone EOR project. However, joint development with the M Sand could enable the J Sand to also be included in a CO₂ EOR project.

Exhibit 2-5. Horn Mountain oil resources, cumulative production, and remaining reserves

Sands	Oil Area (Acres)	OOIP (MMbbls)	Cumulative Oil Production ^A (MMbbls)	Remaining Oil Reserves ^A (MMbbls)
Major Sands				
M	5,800	367	106.2	15.2
Minor Sands				
J	690	40	11.4	2.9
N-Lower	80	4	0	1.8
Total	6,570	411	117.6	19.9

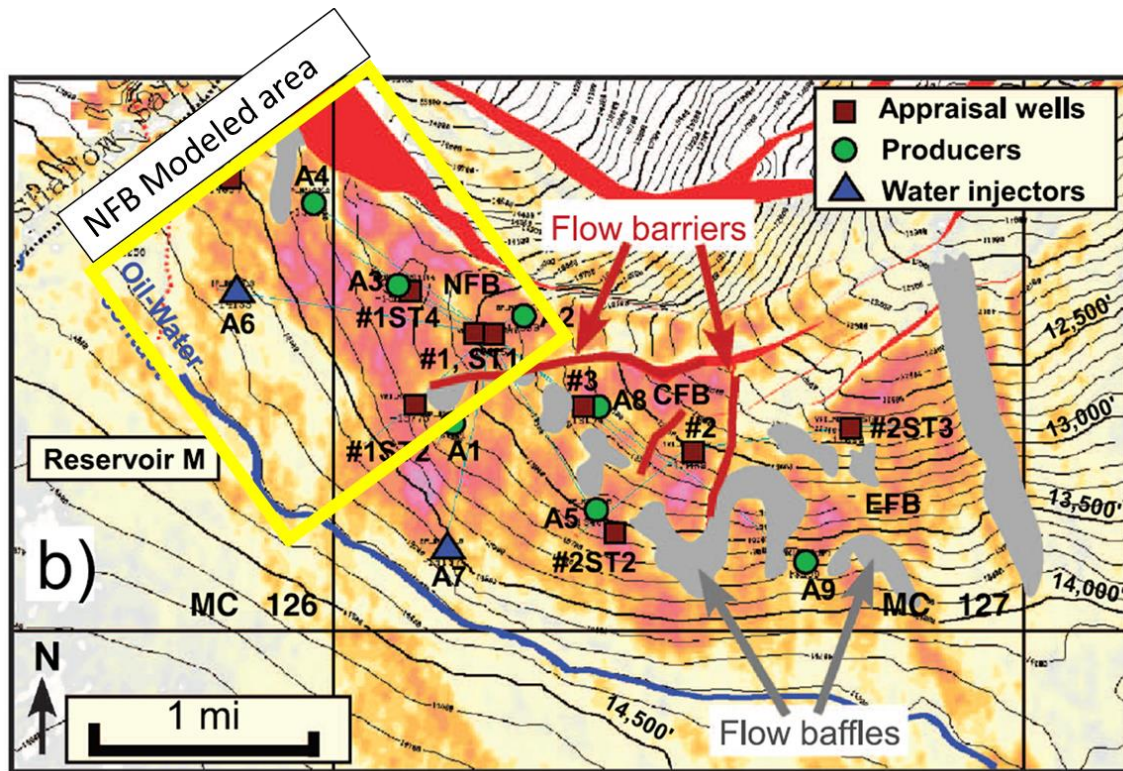
^AAs of end of 2017

Source: Bureau of Ocean Energy Management (BOEM) data, 2018

3 HORN MOUNTAIN NFB M SAND

The reservoir modeling addresses the M Sand in the NFB of Horn Mountain oil field, as identified by the yellow outline in Exhibit 3-1. The M sand in NFB has been developed with three production wells (A4, A3, and A2) and one water injection well (A6). As of the end of 2018, the three production wells are still active; however, water injection well A6 is currently inactive. Exhibit 3-2 provides the key volumetric and reservoir properties for the Horn Mountain NFB M Sand.

Exhibit 3-1. Horn Mountain NFB M Sand oil production and water injection wells



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Exhibit 3-2. Reservoir properties, Horn Mountain NFB M Sand

Property	Value
Accessible Oil Area (acres)	985
Porosity (%)	27
Permeability Horizontal (mD)	250
Permeability Vertical (mD)	25
Permeability Anisotropy	15 to 1
Net Pay (ft)	132
Oil Gravity (°API)	32
Swi	0.22
Soi	0.78
Boi (rb/stb)	1.38
OOIP (MMbbls)	154
Gas/Oil Ratio (scf/bbl)	803
Initial Pressure (at 14,250 ft) (psia)	7,675
Initial Reservoir Temperature (°F)	200

Based on the reservoir properties in Exhibit 3-2, the OOIP for the NFB M Sand is 154 MMbbls, as calculated below:

$$\begin{aligned}
 \text{OOIP} &= (A * F) * 7,758 (\phi * \text{Soi}/\text{Boi}) \\
 &= (985 * 132) * 7,758 \text{ B/AF} (0.27 * 0.78/1.38) \\
 &= 154 \text{ MMbbls}
 \end{aligned}$$

In the OOIP equation above, A is the accessible oil area, F is the average payzone net thickness, Soi is the initial oil saturation, and ϕ is reservoir porosity. Oil production from the NFB M Sand reached a peak of 24,900 bbl/d in 2004 and declined steadily until 2011, with a brief uptick in production between 2012 and 2014. After 2014, oil production resumed its decline to a current (2018) rate of 4,010 bbl/d. Exhibit 3-3 illustrates the oil production history for the three production wells in the Horn Mountain NFB M Sand. As of the end of 2018, the Horn Mountain NFB M Sand had produced 64.7 MMbbls of oil. [7]

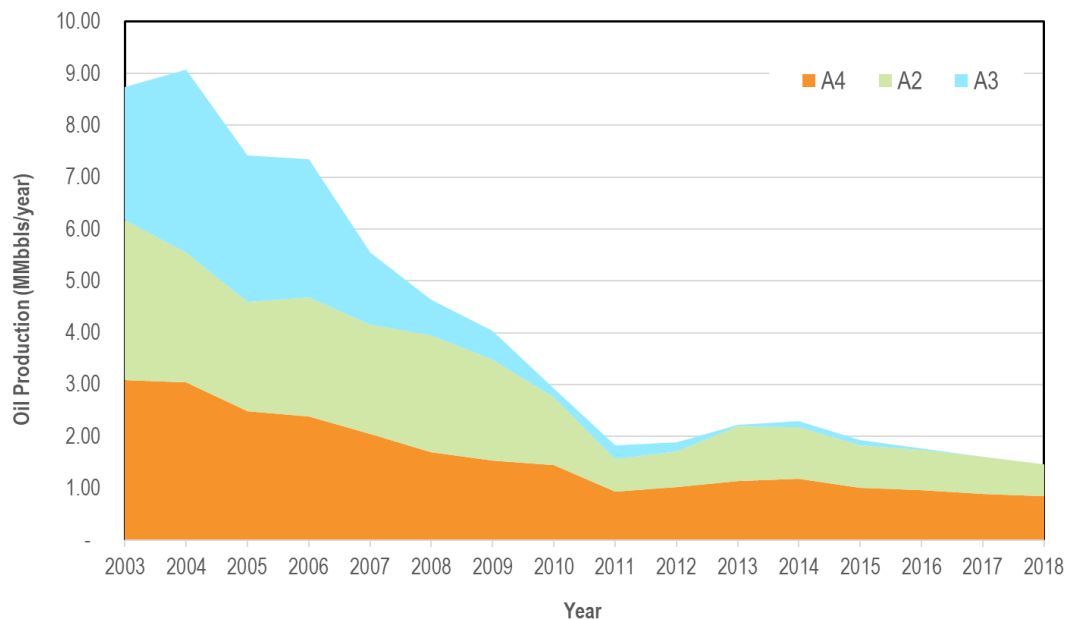
Exhibit 3-3. Horn Mountain NFB M Sand oil production (MMbbls/year) 2003–2018

Exhibit 3-4 provides tabular data on the annual oil production history for the three Horn Mountain NFB M Sand oil production wells.

Exhibit 3-4. Horn Mountain oil field NFB M Sand oil production 2003–2018

Year	Well A004	Well A003	Well A002	Total (MMbbls)
2003	3.1	2.6	3.1	8.7
2004	3.0	3.5	2.5	9.1
2005	2.5	2.8	2.1	7.4
2006	2.4	2.7	2.3	7.3
2007	2.0	1.4	2.1	5.5
2008	1.7	0.7	2.3	4.6
2009	1.5	0.6	1.9	4.0
2010	1.4	0.2	1.3	2.9
2011	0.9	0.3	0.6	1.8
2012	1.0	0.2	0.7	1.9
2013	1.1	0.0	1.1	2.2
2014	1.2	0.1	1.0	2.3
2015	1.0	0.1	0.8	1.9
2016	1.0	0.0	0.8	1.8
2017	0.9	0.0	0.7	1.6
2018	0.9	0.0	0.6	1.5
Total	25.7	15.1	23.9	64.7

Exhibit 3-5 provides a summary of water injection data from 2003 to 2011 for the waterflood in the Horn Mountain oil field NFB M Sand. A total of 6.1 MMbbls of water was injected over eight years. [7]

Exhibit 3-5. Horn Mountain oil field NFB M Sand water injection 2003–2011

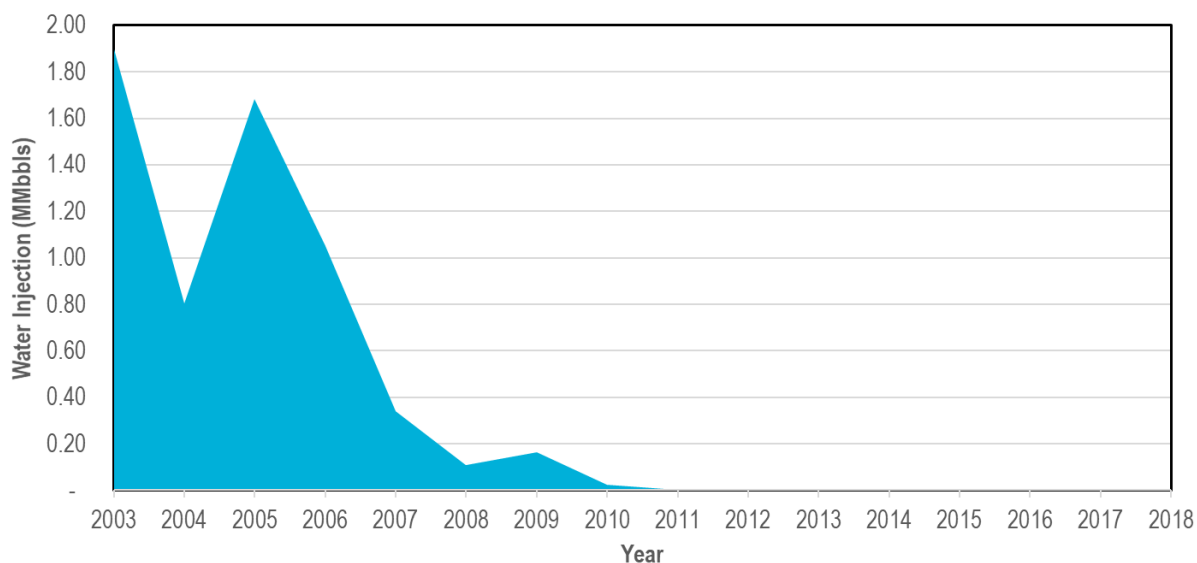


Exhibit 3-6 and Exhibit 3-7 provide the hydrocarbon composition and binary interaction coefficients for the 32° American Petroleum Institute (API) gravity oil in the Horn Mountain oil field NFB M sand with a gas/oil ratio of 803 standard cubic feet (scf)/bbl. The oil composition used for the GEM model was based on data from Li et al. (2017) for a Wolfcamp reservoir oil with similar API gravity and reservoir characteristics [8]

Exhibit 3-6. Oil composition, Horn Mountain NFB M Sand

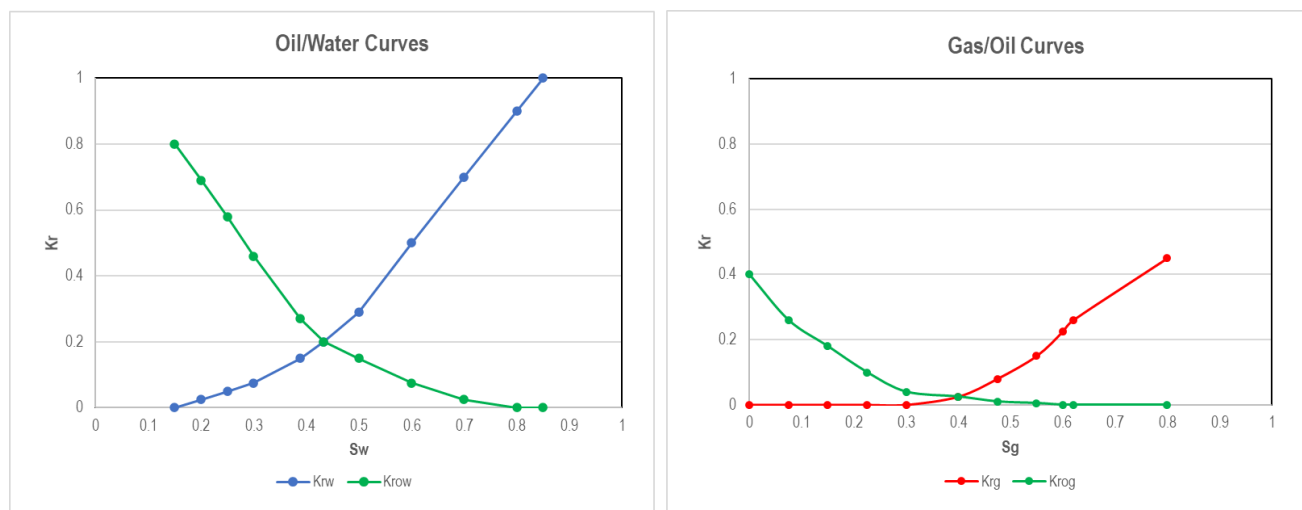
Component	Composition (%)
CO ₂	0.35
N ₂	1.16
C1	35.32
C2	8.66
C3	8.55
iC4	1.06
C4	4.86
C5–C6	7.66
C7–C12	15.70
C13–C21	8.50
C22+	8.23

Exhibit 3-7. Binary interaction coefficients used for the Horn Mountain oil field NFB M Sand

Component	Pc (atm)	Tc (K)	MW	Binary Interaction Coefficients							
				CO ₂	N ₂	C1	C2	C3	IC4	NC4	C5-C6
CO ₂	72.8	304.2	44.01	0							
N ₂	33.5	126.2	28.01	0	0						
C1	45.4	190.6	16.04	0.105	0.025	0					
C2	48.2	305.4	30.07	0.13	0.01	0.0027	0				
C3	41.9	369.8	44.09	0.125	0.09	0.0085	0.0017	0			
IC4	36	408.1	58.12	0.12	0.095	0.0157	0.0055	0.0011	0		
NC4	37.5	425.2	58.12	0.115	0.095	0.0147	0.0049	0.0009	0.0000	0	
C5-6	31.4	486.4	78.3	0.115	0.1	0.0319	0.0165	0.0077	0.0030	0.0035	0
C7-12	24.7	585.1	120.6	0.115	0.11	0.0470	0.0279	0.0162	0.0089	0.0097	0.0016
C13-21	17.0	740.1	220.7	0.115	0.11	0.1003	0.0728	0.0539	0.0402	0.0417	0.0218
C22-80	12.9	1024	443.5	0.115	0.11	0.1266	0.0964	0.0750	0.0590	0.0608	0.0365

Source: Modified from Li, 2017. [8]

Exhibit 3-8 provides the relative permeability curves for oil/water and gas/oil based on history matching Horn Mountain NFB M Sand fluid production.

Exhibit 3-8. Relative permeability curves for oil/water and gas/oil, Horn Mountain oil field NFB M Sand


4 RESERVOIR MODEL FOR THE HORN MOUNTAIN OIL FIELD NFB M SAND

This section describes the construction and calibration of the reservoir model for the Horn Mountain oil field NFB M Sand. Also, this section discusses calibration of the reservoir model.

4.1 CONSTRUCTING THE RESERVOIR MODEL

Exhibit 4-1 illustrates the structure and depth of the Horn Mountain NFB M Sand as well as the location of the three oil production wells (A4, A3, and A2) and the location of the water injection well (A6). A northeast to southwest 7-degree dip was implemented, based on reported wellbore locations. The structure around production well A2 is very complex, so A2 elevation in the model is approximate. [7]

Exhibit 4-1. Horn Mountain oil field M Sand structure and depth

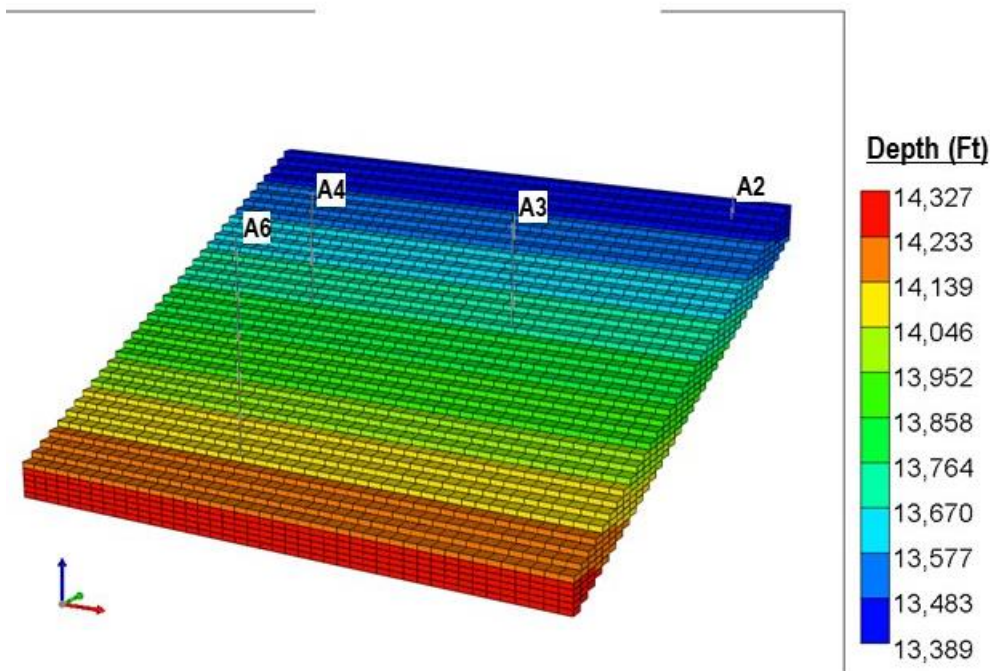
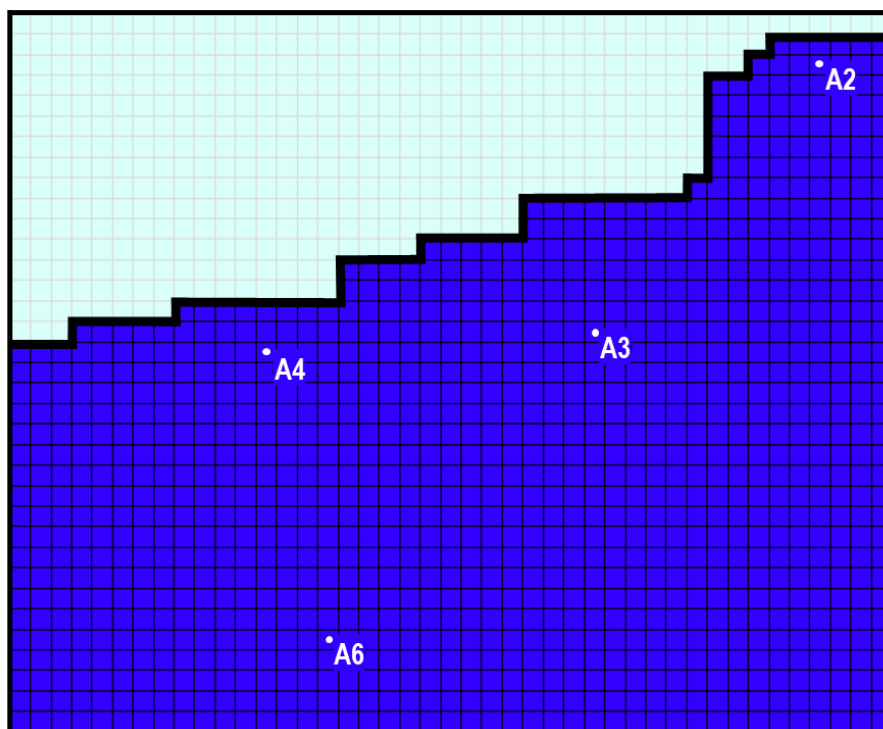


Exhibit 4-2 shows the reservoir model's grid blocks for the Horn Mountain oil field NFB M Sand and its associated aquifer. The model area is defined by 43 x-direction and 35 y-direction grid blocks. With each grid block representing 200 square feet, the total model area encompasses 1,380 acres. A fault along the northern portion of the fault block reduces the productive area of the NFB M Sand to 985 acres.

The model contains six vertical grid blocks, each 22 ft thick, to provide higher resolution and to model gravity effects on injected and produced fluids. The bottom grid block represents the oil-water contact at 14,300 feet reservoir depth. The light blue portion of Exhibit 4-2 represents the area on the north of the NFB area, separated from the oil-bearing M Sand by a major fault. [7]

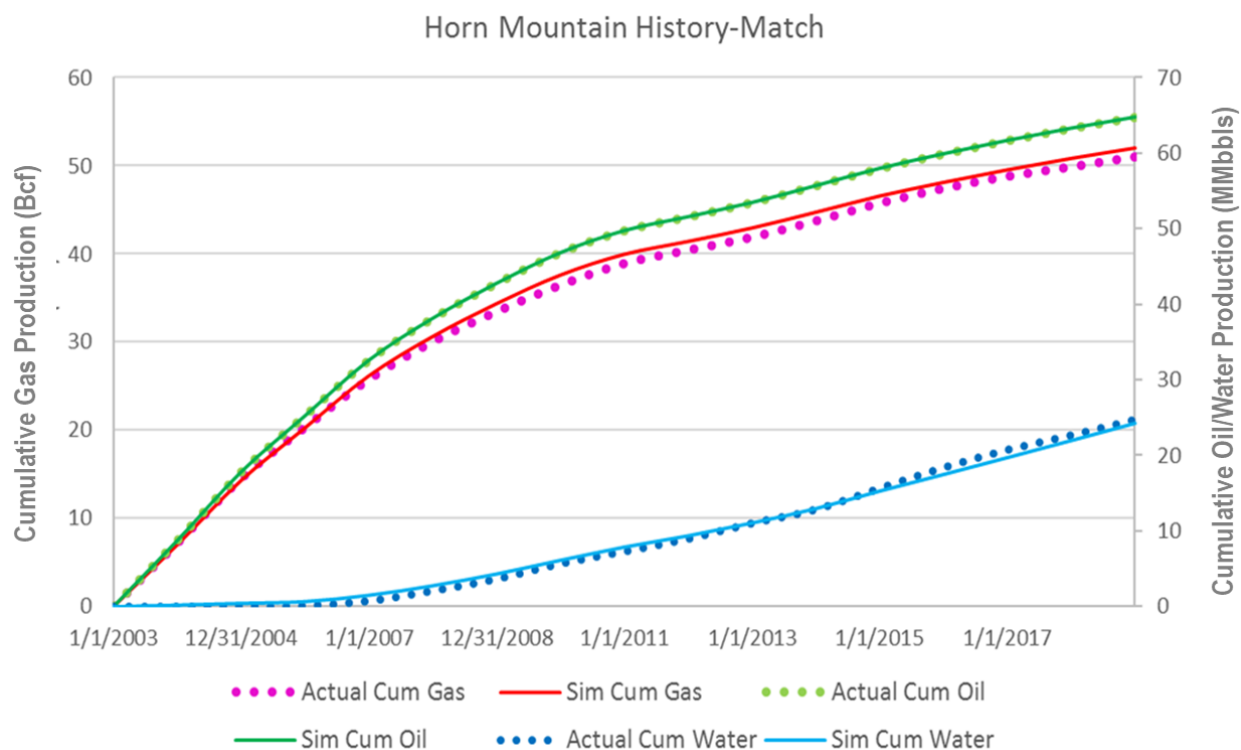
Exhibit 4-2. Horn Mountain oil field M Sand reservoir model and grid blocks



4.2 CALIBRATING THE RESERVOIR MODEL

To calibrate the Horn Mountain oil field, the study assembled a data set representative of the Horn Mountain NFB M Sand to perform a “first-order” history match of the oil, gas, and water production reported for the M Sand for the period 2003 through 2018. (Actual pressure data were not available in the BOEM data set or in the technical literature.) Reported fluid production values were closely matched with the GEM compositional simulator, using the M Sand structure, its reservoir properties, and other parameters, as shown in Exhibit 4-3 [7] and Exhibit 4-4. [7]

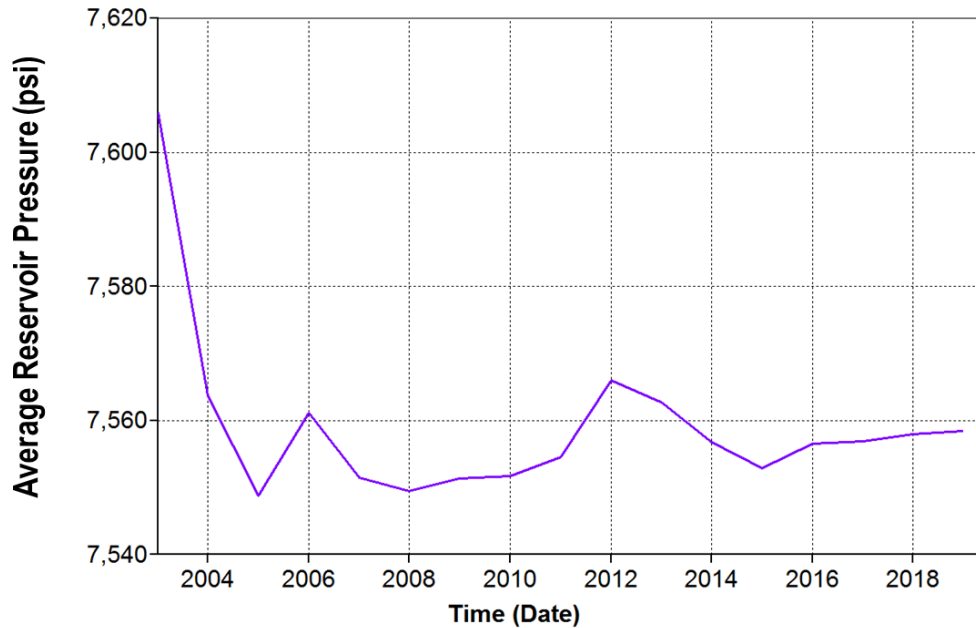
For the history match, the oil production rate in GEM was constrained to match the actual production rate observed from the three production wells in the NFB M Sand. Since gas is in solution, gas production was controlled using the gas/oil ratio observed in the field. An aquifer was implemented in the model to match water production. In addition, 6 MMbbls of water were injected during the waterflood, and a total of 24 MMbbls of water were produced in the history match consistent with actual water injection and production data. Additional data and information on well by well production from the “first-order” history match are provided in Appendix A.

Exhibit 4-3. History match of cumulative fluid production, Horn Mountain oil field NFB M Sand**Exhibit 4-4. Comparison of actual and history matched values for oil, gas, and water production, Horn Mountain oil field NFB M Sand**

Fluid	Actual Data	History Matched Data
Oil (MMbbls)	64.7	64.7
Gas (Bcf)	51	52
Water (MMbbls)	24.8	24.3

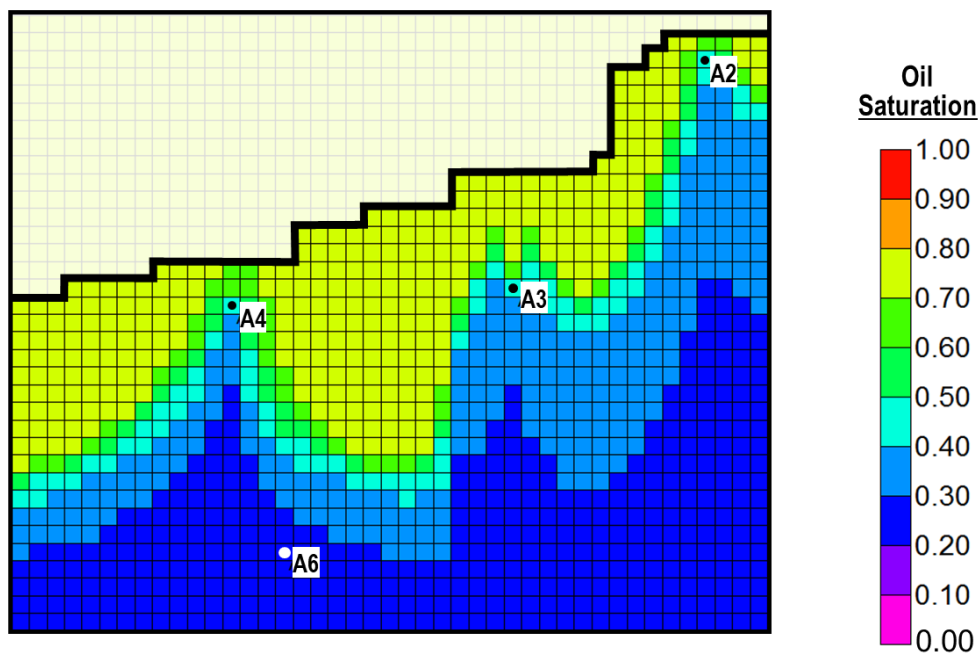
An important output of the history match was the estimate of NFB M Sand reservoir pressure at the end of primary production (Exhibit 4-5) providing important information for designing CO₂ injectivity and volumes for the proposed miscible CO₂ flood in the M Sand.

Exhibit 4-5. Reservoir pressure from history match of fluid production, Horn Mountain oil field NFB M Sand



A most important outcome of the history matching step was establishing the location of the oil saturations remaining in the Horn Mountain oil field NFB M Sand reservoir at the end of the waterflood (Exhibit 4-6). [7] This information helped establish the optimum locations for placing the new CO₂ injection wells in the proposed CO₂ flood.

Exhibit 4-6. Oil saturation at end of waterflood, Horn Mountain oil field NFB M Sand



5 GEM MODELING THE PERFORMANCE OF THE CO₂ FLOOD, HORN MOUNTAIN OIL FIELD NFB M SAND

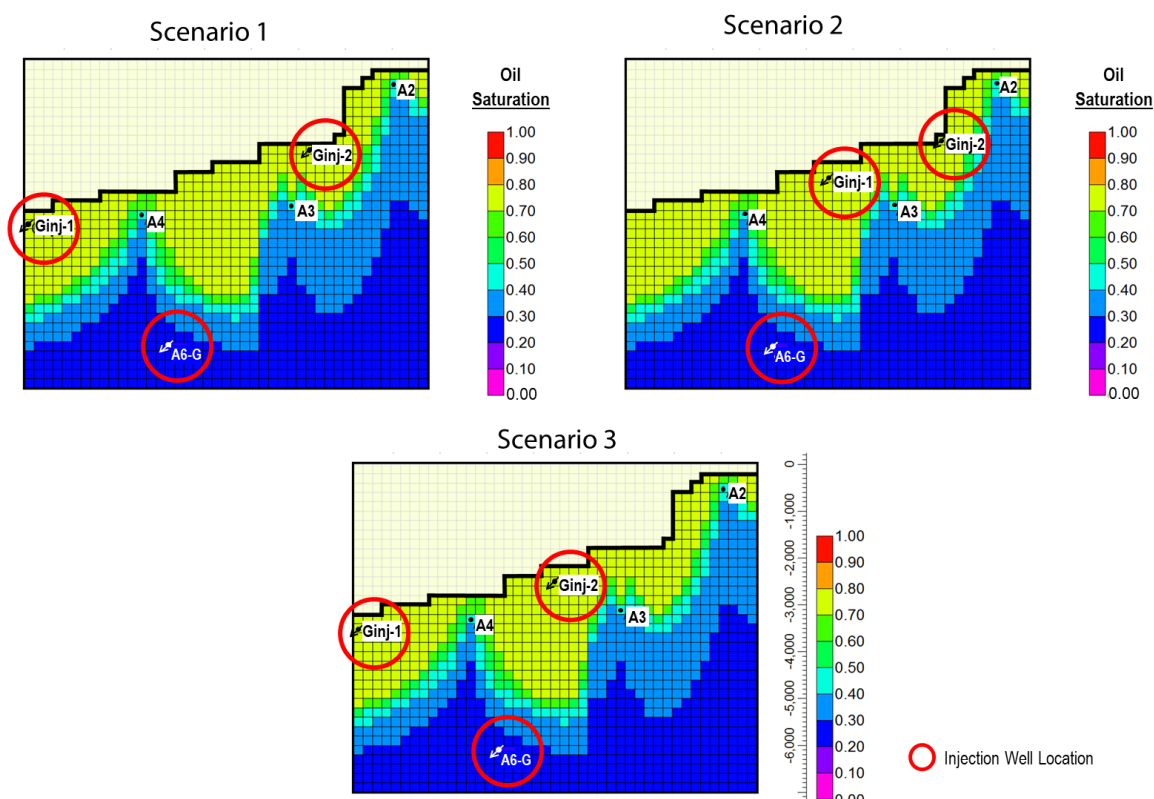
The reservoir model constructed for the Horn Mountain oil field NFB M Sand (Section 4) was placed into the GEM reservoir simulator to evaluate the expected performance of the CO₂ flood.

5.1 CO₂ FLOOD DESIGN

To optimize the CO₂ flood in the NFB M Sand, this case study set forth three CO₂ injection scenarios. Each scenario represents a different set of CO₂ injection well placements targeting areas of the reservoir with high remaining oil saturations (Exhibit 5-1):

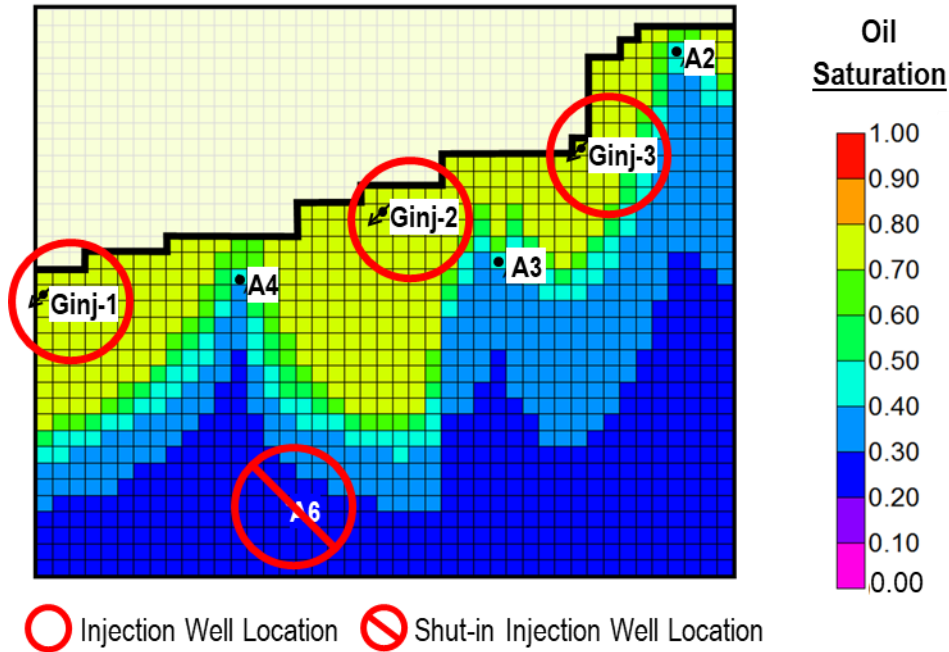
- Each of the three CO₂ flooding scenarios drilled two new up dip CO₂ injection wells between the existing oil production wells and the fault in the northwest portion of the NFB and converted the existing water injection well (A6) to a CO₂ injection well
- Each scenario injected continuous CO₂ at a rate of 72 MM cubic feet per day (cfd) (24 MMcfd for three injection wells) into the NFB M Sand for 20 years, using a maximum bottom hole pressure of 9,000 psi
- Each scenario used a line drive pattern, with a 1:1 injector-to-producer ratio, for the CO₂ flood design

Exhibit 5-1. Horn Mountain oil field NFB M Sand CO₂ injection wells and post waterflood oil saturation, scenarios 1–3



In addition to the three scenarios discussed above, the study examined a more capital-intensive fourth scenario involving drilling three new CO₂ injection wells and shutting in the currently inactive A6 water injection well (Exhibit 5-2).

Exhibit 5-2. Horn Mountain oil field NFB M Sand CO₂ injection wells and post waterflood oil saturation, scenario 4

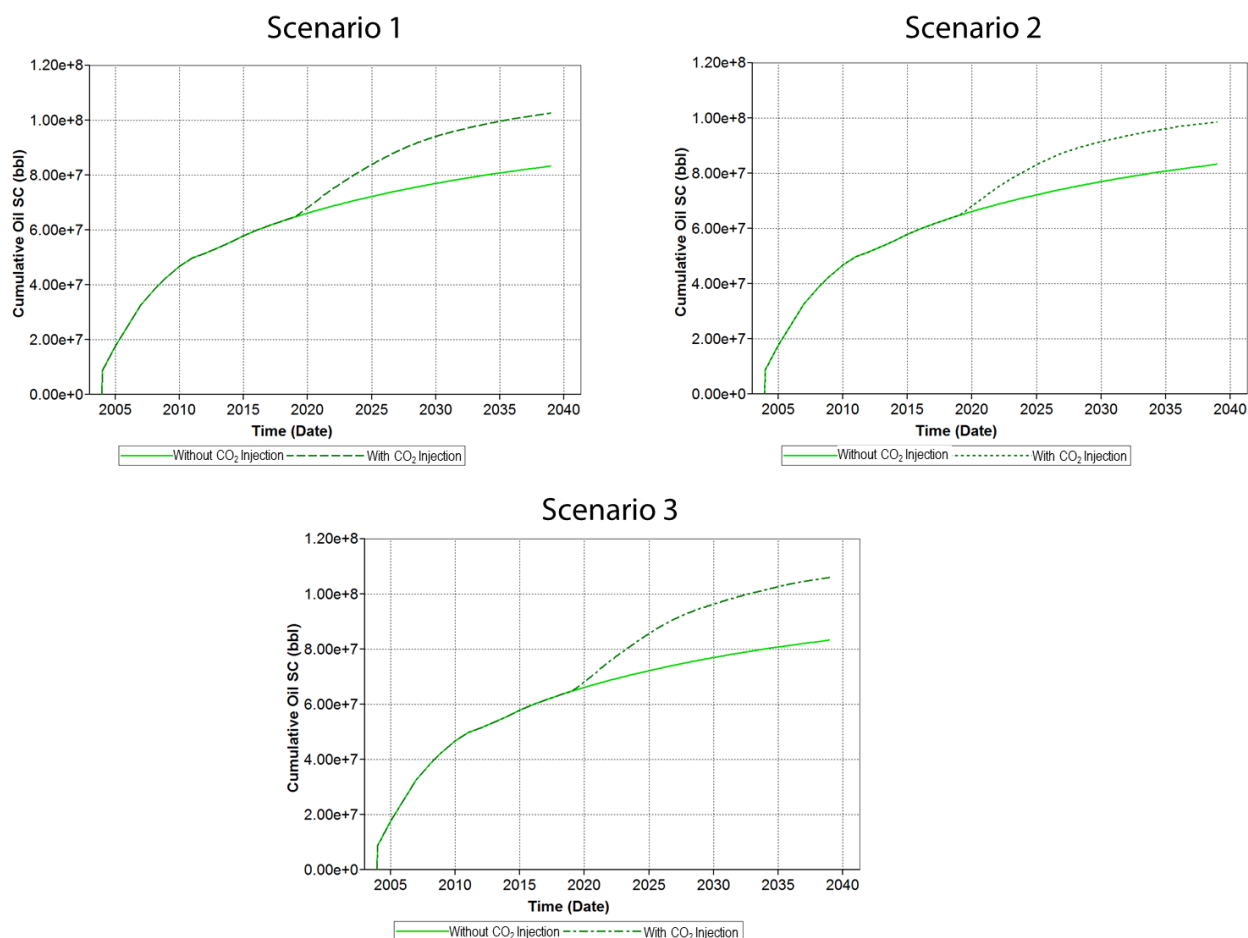


5.2 CALCULATED OIL RECOVERY

GEM modeling of the CO₂ flood in the Horn Mountain oil field NFB M Sand provided the following volumes of incremental oil recovery (beyond primary and waterflood) following 20 years of CO₂ injection (Exhibit 5-3).

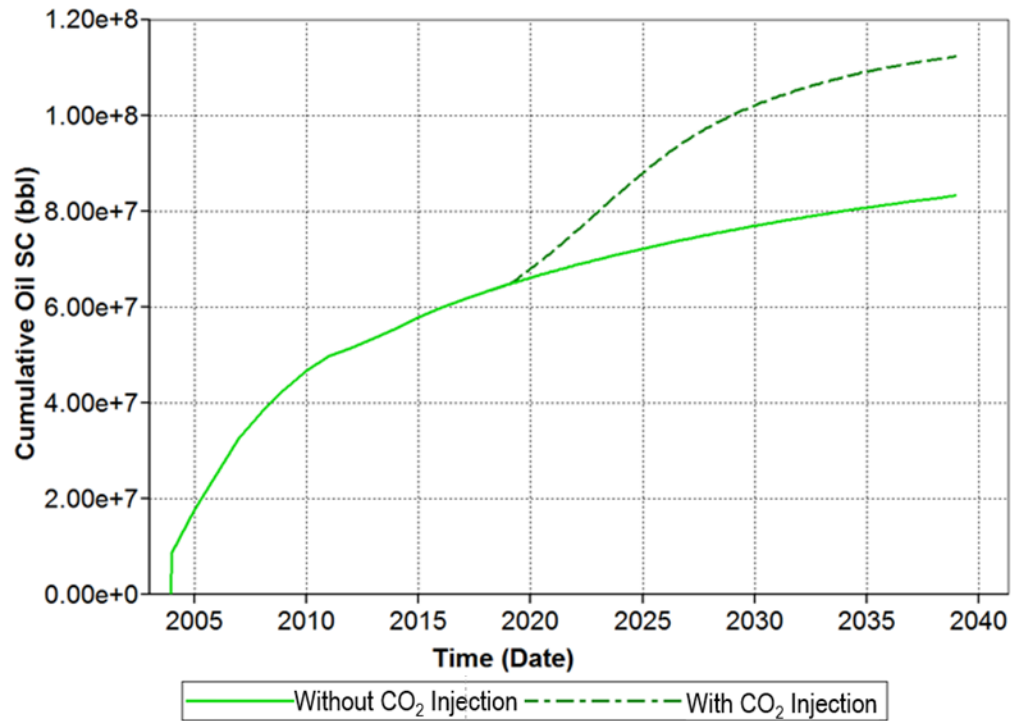
- Scenario 1 – 19.2 MMbbl of incremental oil recovery, equal to 12.5 percent of OOIP
- Scenario 2 – 15.5 MMbbl of incremental oil recovery, equal to 10.1 percent of OOIP
- Scenario 3 – 22.5 MMbbl of incremental oil recovery, equal to 14.6 percent of OOIP

Exhibit 5-3. Horn Mountain oil field NFB M Sand cumulative oil recovery with and without CO₂ injection, scenarios 1–3



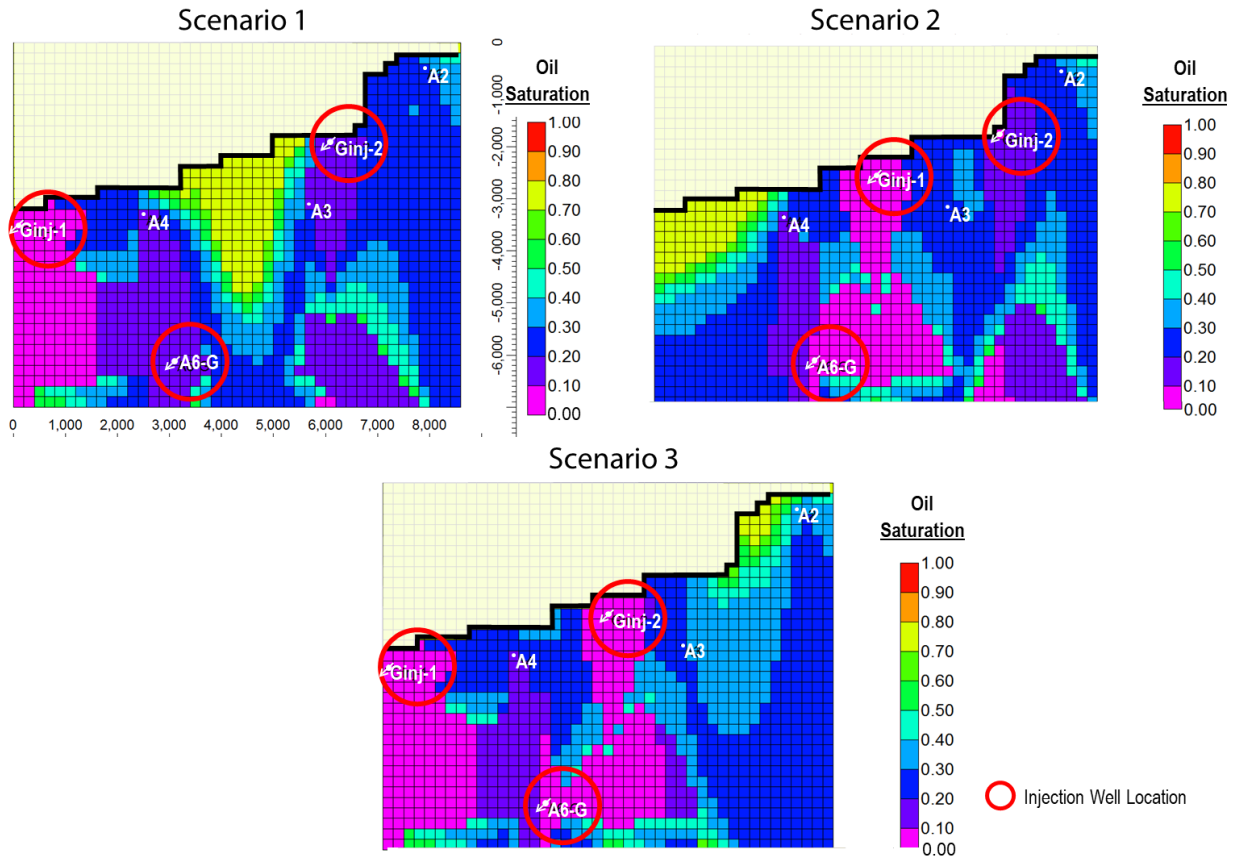
The more capital-intensive Scenario 4 CO₂ flood achieved 29.0 MMbbls of oil recovery, equal to 18.8 percent of OOIP (Exhibit 5-4).

Exhibit 5-4. Horn Mountain oil field NFB M Sand cumulative oil recovery with and without CO₂ injection, scenario 4

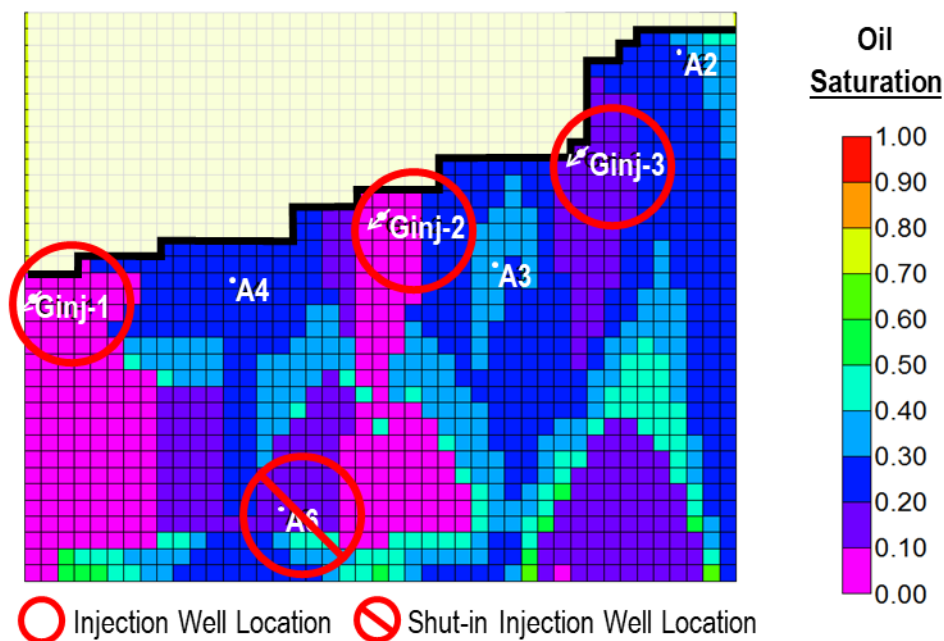


A review of the performance of the three main CO₂ flooding scenarios shows that Scenario 3 achieved the highest contact with the NFB M sand, while leaving behind the lowest residual oil saturation (Exhibit 5-5).

Exhibit 5-5. Horn Mountain oil field NFB M Sand CO₂ injection wells and post CO₂ flood oil saturation, scenarios 1–3



By drilling three new up dip CO₂ injection wells, Scenario 4 contacted more of the residual oil saturation of the M Sand in NFB, enabling this more costly and sophisticated CO₂ EOR flood to maximize oil recovery (Exhibit 5-6).

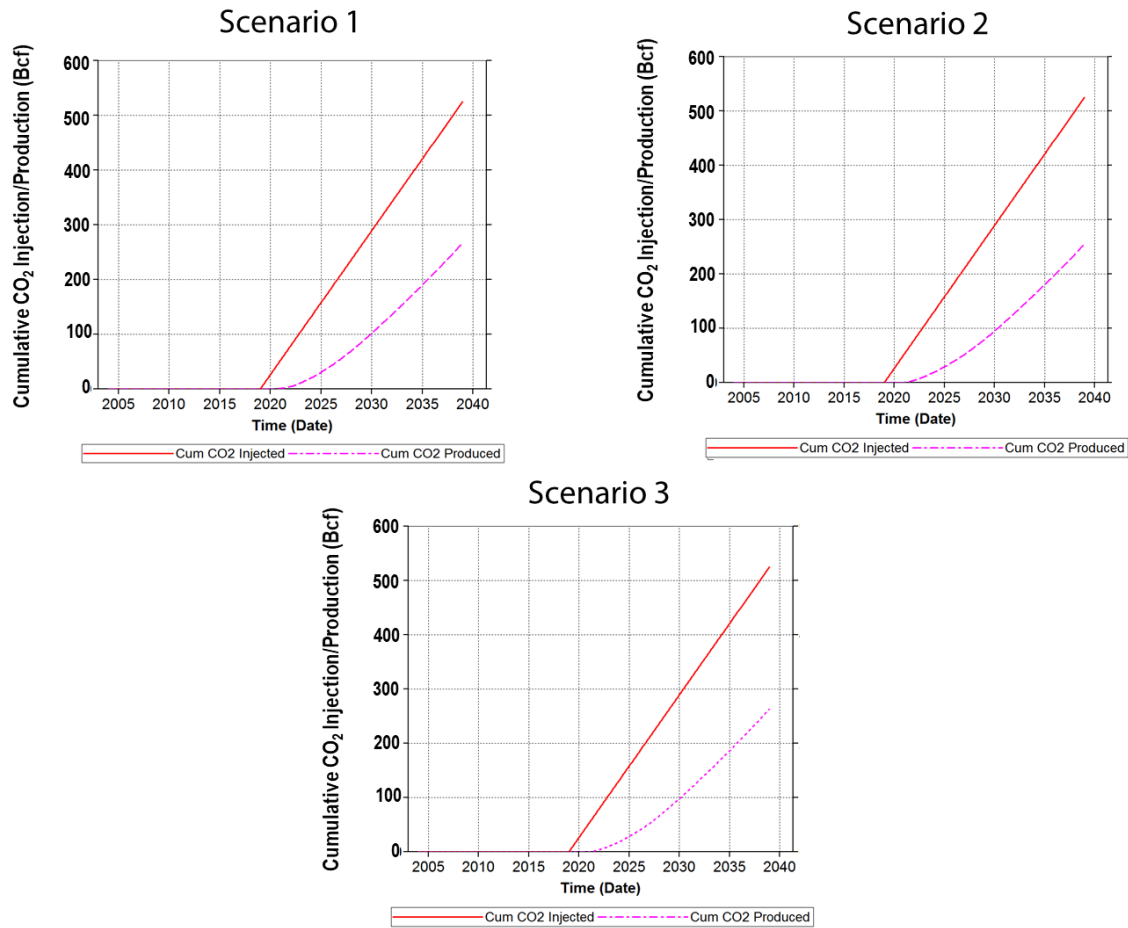
Exhibit 5-6. Horn Mountain oil field NFB M Sand CO₂ injection wells and post CO₂ flood oil saturation, scenario 4

5.3 CALCULATED CO₂ INJECTION, PRODUCTION, AND STORAGE

GEM modeling of the CO₂ flood in the Horn Mountain oil field NFB M Sand also provided the following data on CO₂ production and storage for the 20-year CO₂ flood (Exhibit 5-7). Each scenario used gross CO₂ injection of 526 Bcf into three CO₂ injection wells.

- Scenario 1 – Production and recycling of 255 Bcf for total storage of 271 Bcf
- Scenario 2 – Production and recycling of 268 Bcf for total storage of 258 Bcf
- Scenario 3 – Production and recycling of 264 Bcf for total storage of 262 Bcf

Exhibit 5-7. Horn Mountain oil field NFB M Sand cumulative CO₂ injection and production, scenarios 1–3



With increased reservoir contact and higher oil recovery, Scenario 4 is also able to provide notably higher volumes of CO₂ storage (Exhibit 5-8).

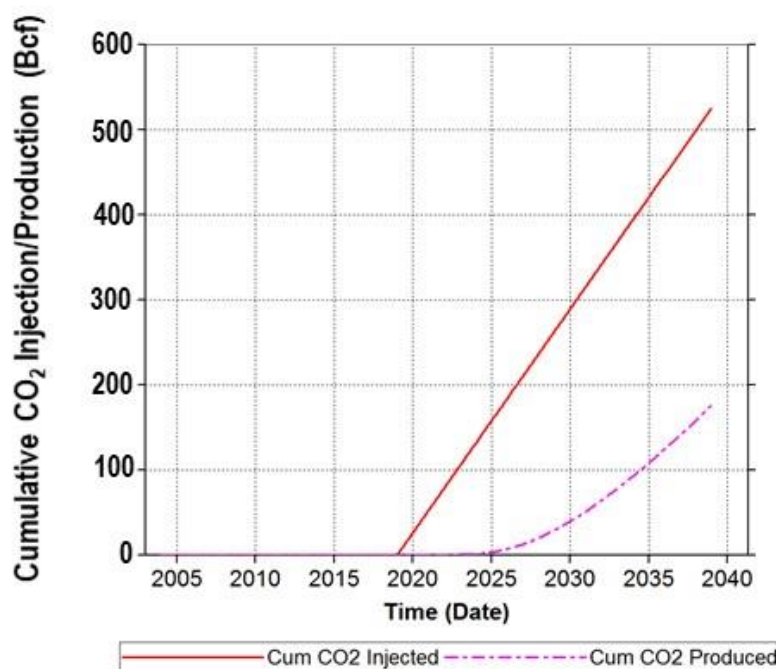
Exhibit 5-8. Horn Mountain oil field NFB M Sand cumulative CO₂ injection and production, scenario 4

Exhibit 5-9 provides the cumulative data for oil production, the cumulative data for CO₂ injection and storage, and the gross and net CO₂ utilization for CO₂ EOR for scenarios 1–3 in the Horn Mountain oil field NFB M Sand. For the 20-year CO₂ flood, gross CO₂ utilization is between 23.4 thousand cubic feet (Mcf)/bbl and 33.9 Mcf/bbl. Net CO₂ utilization is between 11.6 Mcf/bbl and 16.6 Mcf/bbl, equal to 0.61 to 0.88 metric tons of CO₂ stored per bbl of oil recovered.

Exhibit 5-9. Oil production, CO₂ injection, CO₂ storage, and CO₂ utilization; GEM compositional modeling of the CO₂ flood Horn Mountain oil field NFB M Sand

Scenario	Incremental Oil Production	Cumulative CO ₂		CO ₂ Utilization	
	Cumulative (MMbbls)	Injection (Bcf)	Storage (Bcf)	Gross (Mcf/bbl)	Net (Mcf/bbl)
1	19.2	526	271	27.4	14.1
2	15.5	526	258	33.9	16.6
3	22.5	526	262	23.4	11.6

The Scenario 4 CO₂ flood, involving additional well drilling and capital investment, provided higher values for oil recovery and CO₂ storage—29.0 MMbbls for oil recovery and 350 Bcf for CO₂ storage—than achieved by scenarios 1, 2, or 3 CO₂ floods. An economic assessment, not performed by this case study, would be required to establish under what oil price outlooks the extra capital expenditures incurred by Scenario 4 would be justified by the higher volumes of oil recovery and CO₂ storage.

6 MODELING THE PERFORMANCE OF THE HORN MOUNTAIN OIL FIELD NFB M SAND CO₂ FLOOD WITH CO₂ PROPHET MODEL

In parallel with GEM, the CO₂ Prophet Model was used to evaluate the expected performance of the CO₂ flood in the Horn Mountain oil field NFB M Sand using the volumetric and reservoir properties data established in Section 3. Exhibit 6-1 provides the volumetric and reservoir property data for the Horn Mountain oil field total M Sand. Exhibit 6-2 provides the key volumetric and reservoir property data for modeling the Horn Mountain oil field NFB M Sand. Exhibit 6-3 and Exhibit 6-4 are the input data sheets for modeling the CO₂ flood in the Horn Mountain oil field M Sand using the CO₂ Prophet Model.

To capture the heterogeneity of the M Sand, a Dykstra-Parsons (DP) coefficient of 0.75 was first used in CO₂ Prophet modeling. The impact of using a more favorable DP coefficient of 0.5, that would represent a considerably more uniform reservoir sand, was also examined.^a

6.1 USE OF DYKSTRA-PARSONS (DP) TO CAPTURE FEATURES NOT AVAILABLE IN THE CO₂ PROPHET MODEL

Because CO₂ Prophet does not handle gravity override or reservoir heterogeneity in a CO₂ flood (important features that are captured by the GEM Model), we use the DP function to represent these features. The DP function in CO₂ Prophet places the higher perm layers at the top of the reservoir, partially capturing the effects of gravity override by the CO₂. A higher DP value in CO₂ Prophet can also be used to capture the effects of reservoir heterogeneity due to anisotropy and other reasons. In general, a DP value of 0.5 represents a favorable, relatively thin offshore reservoir. A value of 0.75 is commonly used to represent a favorable but thicker and more heterogeneous, onshore reservoir.

With no means of directly modeling anisotropy or CO₂ override in CO₂ Prophet, the DP value is the best “control knob” that the study has for approximating the effects of these features on reservoir performance. We bracketed the results with two DPs to show a range of outcomes relative to the GEM model results.

^a The DP coefficient is used by the reservoir engineering community to define the heterogeneity of a reservoir, with a low value (0.5 or so) reflecting low heterogeneity and a high value (0.9 or so) reflecting high heterogeneity. A full-scale, compositional reservoir model typically assigns different permeability values to discrete units of net pay (the vertical stack of grid blocks) to capture the reservoir heterogeneity.

Exhibit 6-1. Volumetric and reservoir properties, Horn Mountain oil field total M Sand

Basin Name	FED-OFF	Area:	Offshore	^ To change Basin, click on cell above v
State	LA	Reservoir Number	23469	
Field Name	MC084 – Horn Mountain	Manual	23469	
Reservoir	M Sand	Total Reservoirs	595	

Reservoir Parameters:		Oil Production		Volumes	
Area (A)	5,803	Producing Wells (active)	7	OOIP (MMbl)	103 366.9
Net Pay (ft)	57	Producing Wells (shut-in)	0	Cum P/S Oil (MMbl)	106.2
Depth (ft)	14,250	2018 Production (MMbbl)	2.16	EOY 2018 P/S Reserves (MMbl)	15.2
Lithology	1	2018 P/S Production (MMbbl)	2.16	Ultimate P/S Recovery (MMbl)	121.4
Dip (°)	0	Cum Oil Production (MMbbl)	106.2	Remaining (MMbbl)	245.5
Gas/Oil Ratio (Mcf/Bbl)	803	EOY 2018 Oil Reserves (MMbbl)	15.2	Ultimate P/S Recovered (%)	33%
Salinity (ppm)	98,376	Water Cut	65.7%	P/S Sweep Efficiency (%)	106 63%
Gas specific Gravity	0.62	Water Production		OOIP Volume Check	
Historical Well Spacing (Acres)	-1	2018 Water Production (Mbbl)	4.1	Reservoir Volume (AF)	333,116
Current Pattern Acreage (Acres)	160	Daily Water (Mbbl/d)	0.0	Bbl/AF	1,101.4
Permiability (mD)	250	Injection		OOIP Check (MMbl)	366.9
Porosity (%)	24%	Injection Wells (active)	2	SROIP Volume Check	
Reservoir Temp (deg F)	203	Injection Wells (shut-in)	0	Reservoir Volume (AF)	333,116
Initial Pressure (psi)	7675	2018 Water Injection (MMbbl)	0	Swept Zone Bbl/AF	527
Pressure (psi)	-1	Daily Injection - Field (Mbbl/d)	0.00	SROIP Check (MMbbl)	175.5
B _{oi}	1.32	Cum Injection (MMbbl)	0.0	ROIP Volume Check	
B _o @ S _{oi} swept	1.15	Daily Inj per Well (Bbl/d)	0.0	ROIP Check (MMbl)	245.5
S _{oi}	0.78	EOR			
S _{or}	0.325	Type	0		
S _{wi}	0.22	2018 EOR Production (MMbbl)	0.0		
S _w	0.675	Cum EOR Production (MMbbl)	0.0		
API Gravity	32.0	EOR 2018 Reserves (MMbbl)	0.0		
Viscosity (cp)	0.69	Ultimate Recovery (MMbbl)	0.0		
Dykstra-Parsons	0.85	OGJ Data			
Miscibility:		2018 Enhanced Production (B/d)	0		
C5+ Oil Composition	208.1	2018 Total Production (B/d)	0		
Min Required Miscibility Press(psig)	2825.4	Project Acreage	0		
Depth > 3000 feet	1	Scope	0		
API Gravity >= 17.5	1	# Projects	0		
Pr > MMP	0				
Flood Type	Miscible				

Exhibit 6-2. Volumetric and reservoir properties, Horn Mountain oil field NFB M Sand

Basin Name	FED-OFF	Area:	Offshore
State	LA	To change Basin, click on cell above	
Field Name	MC084 – Horn Mountain	Reservoir Number	23469
		Manual	23469
Reservoir	NFB M Sand	Total Reservoirs	595

^
v

Reservoir Parameters:		Oil Production		Volumes	
Area (A)	985	Producing Wells (active)	3	OOIP (MMbl)	103 153.9
Net Pay (ft)	132	Producing Wells (shut-in)	0	Cum P/S Oil (MMbl)	64.7
Depth (ft)	14,250	2018 Production (MMbbl)	1.46	EOY 2018 P/S Reserves (MMbl)	10.3
Lithology	1	2018 P/S Production (MMbbl)	1.460	Ultimate P/S Recovery (MMbl)	75.0
Dip (°)	0	Cum Oil Production (MMbbl)	64.7	Remaining (MMbbl)	79.0
Gas/Oil Ratio (Mcf/Bbl)	803	EOY 2018 Oil Reserves (MMbbl)	10.3	Ultimate P/S Recovered (%)	49%
Salinity (ppm)	98,376	Water Cut	58.5%	P/S Sweep Efficiency (%)	106 97%
Gas specific Gravity	0.62			OOIP Volume Check	
Historical Well Spacing (Acres)	-1	Water Production		Reservoir Volume (AF)	130,026
Current Pattern Acreage (Acres)	160	2018 Water Production (Mbbbl)	2.1	Bbl/AF	1,183.9
Permeability (mD)	250	Daily Water (Mbbbl/d)	0.01	OOIP Check (MMbl)	153.9
Porosity (%)	27%			SROIP Volume Check	
Reservoir Temp (deg F)	203	Injection		Reservoir Volume (AF)	130,026
Initial Pressure (psi)	7675	Injection Wells (active)	1	Swept Zone Bbl/AF	592
Pressure (psi)	-1	Injection Wells (shut-in)	0	SROIP Check (MMbbl)	77.0
		2018 Water Injection (MMbbl)	0		
B _{oi}	1.38	Daily Injection - Field (Mbbbl/d)	0.00	ROIP Volume Check	
B _o @ S _o swept	1.15	Cum Injection (MMbbl)	0.0	ROIP Check (MMbl)	79.0
S _{oi}	0.78	Daily Inj per Well (Bbl/d)	0.0		
S _{or}	0.325	EOR			
S _{wi}	0.22	Type	0		
S _w	0.675	2018 EOR Production (MMbbl)	0.0		
		Cum EOR Production (MMbbl)	0.0		
API Gravity	32.0	EOR 2018 Reserves (MMbbl)	0.0		
Viscosity (cp)	0.69	Ultimate Recovery (MMbbl)	0.0		
		OGJ Data			
Dykstra-Parsons	0.75	2018 Enhanced Production (B/d)	0		
Miscibility:		2018 Total Production (B/d)	0		
C5+ Oil Composition	208.1	Project Acreage	0		
Min Required Miscibility Press(psig)	2825.4	Scope	0		
Depth > 3000 feet	1	# Projects	0		
API Gravity >= 17.5	1				
Pr > MMP	0				
Flood Type	Miscible				

Exhibit 6-3. Input datasheet, CO₂ Prophet modeling of Horn Mountain oilfield NFB M Sand (DP = 0.75)

```

'Horn Mountain -- NFB 985 ac Base Case -- Line Drive -- DP 75'
'***** WELL AND PATTERN DATA *****'
'PATTERN'
'LD'
'NWELLS      NOINJ'
2,           1
'WELLS      WELLY      WELLQ'
0,           0,         1
1,           1,         -1
'NBNDPT'
5
'BOUNDX      BOUNDY'
0,           0
0,           1
1,           1
1,           0
0,           0
'***** PROGRAM CONTROLS *****'
'WGEN      OUTTIM'
'N',       1
'**** RELATIVE PERMEABILITY PARAMETERS ****'
'SORW      SORG      SORM'
0.20,      0.3,      0.1
'SGR      SSR'
0.3,       0.3
'SWC      SWIR'
0.3,       0.3
'KROCW      KWRO      KRSMAX      KRGCW'
0.8,        0.2,      0.4,        0.45
'EXPW      EXPW      EXPS      EXPG      EXPOG'
2,          2,        2,          2,          2
'KRMSSEL    W'
1,          0.999
'***** FLUID DATA *****'
'VISO      VISW'      CO2SOL 0 REDFAC 0.10 CO2INJ
0.69,      0.38
'BO      RS      API      SALN      GSG'
1.15,      804,      32,      98375,      0.62
'***** RESERVOIR DATA *****'
'TRES      P      MMP'
203,       9000,      2825
'DPCOEf      PERMAV      THICK      POROS      NLAYERS'
0.50,       250,      132,      0.27,      10
'SOINIT      SGINIT      SWINIT'
0.325,      0,        0.675
'AREA      XKVH'
42906600,   1
'***** INJECTION PARAMETERS *****'
'NTIMES      WAGTAG'
1,           'T'
'HCPVI      WTRRAT      SOLRAT      TMORVL'
1.04,       27000,      72,        0.0

```

Exhibit 6-4. Input datasheet, CO₂ Prophet modeling of Horn Mountain oil field NFB M Sand (DP = 0.5)

```

'Horn Mountain -- NFB 985 ac Base Case -- Line Drive -- DP 50'
'***** WELL AND PATTERN DATA *****'
'PATTERN'
'LD'
'NWELLS      NOINJ'
2,          1
'WELLS      WELLY      WELLQ'
0,          0,          1
1,          1,          -1
'NBNDPT'
5
'BOUNDX      BOUNDY'
0,          0
0,          1
1,          1
1,          0
0,          0
'***** PROGRAM CONTROLS *****'
'LWGEN      OUTTIM'
'N',        1
'**** RELATIVE PERMEABILITY PARAMETERS ****'
'SORW      SORG      SORM'
0.20,      0.3,      0.1
'SGR      SSR'
0.3,      0.3
'SWC      SWIR'
0.3,      0.3
'KROCW      KWRO      KRSMAX      KRCGW'
0.8,      0.2,      0.4,      0.45
'EXPW      EXPW      EXPS      EXPG      EXPOG'
2,      2,      2,      2,      2
'KRMSEL      W'
1,      0.999
'***** FLUID DATA *****'
'VISO      VISW'      CO2SOL 0 REDFAC 0.10 CO2INJ
0.69,      0.38
'BO      RS      API      SALN      GSG'
1.15,      804,      32,      98375,      0.62
'***** RESERVOIR DATA *****'
'TRES      P      MMP'
203,      9000,      2825
'DPCOEf      PERMAV      THICK      POROS      NLAYERS'
0.50,      250,      132,      0.27,      10
'SOINIT      SGINIT      SWINIT'
0.325,      0,      0.675
'AREA      XKVH'
42906600,      1
'***** INJECTION PARAMETERS *****'
'NTIMES      WAGTAG'
1,      'T'
'HCPVI      WTRRAT      SOLRAT      TMORVL'
1.04,      27000,      72,      0.0

```

6.2 CO₂ FLOOD DESIGN

The structural setting and well locations of the Horn Mountain oil field NFB M Sand were modeled with the CO₂ Prophet Model using the following features:

- Drill two new CO₂ injectors and convert the A6 water injection well into a CO₂ injector; operate the CO₂ flood using a line drive spacing pattern
- Inject continuous CO₂ at a rate of 72 MMcfd for 20 years, reaching a cumulative injection of CO₂ of 528 Bcf, equal to the CO₂ injected in GEM (hydrocarbon pore volume of 1.0).

6.3 CALCULATED OIL RECOVERY

CO₂ Prophet modeling of the CO₂ flood in the Horn Mountain oil field NFB M Sand with a DP coefficient of 0.75 provided incremental oil recovery (beyond the waterflood) of 16.1 MMbbls.

CO₂ Prophet modeling of the CO₂ flood in the Horn Mountain oil field NFB M Sand with a DP coefficient of 0.5 provided incremental oil recovery (beyond the waterflood) of 23.4 MMbbls.

6.4 CO₂ INJECTION, PRODUCTION, AND STORAGE

CO₂ Prophet modeling of the CO₂ flood in the Horn Mountain oil field NFB M Sand provided the following data for CO₂ injection, CO₂ production, and CO₂ storage for a 20-year CO₂ flood.

- For the DP = 0.75 case, CO₂ injection of 528 Bcf, CO₂ production of 312 Bcf, and CO₂ storage of 215 Bcf for a 20-year CO₂ flood, with CO₂ to oil ratios of 32.8 Mcf/bbl (gross) and 13.4 Mcf/bbl (net)
- For the DP = 0.5 case, CO₂ injection of 528 Bcf, CO₂ production of 245 Bcf, and CO₂ storage of 283 Bcf for a 20-year CO₂ flood, with CO₂ to oil ratios 22.6 Mcf/bbl (gross) and 12.1 Mcf/bbl (net)

Exhibit 6-5 (for DP = 0.75) and Exhibit 6-6 (for DP = 0.5) provide the data for oil production, CO₂ injection and CO₂ production for the CO₂ flood in the Horn Mountain oil field NFB M Sand using the CO₂ Prophet Model.

Exhibit 6-5. Oil production, CO₂ injection, and CO₂ production; CO₂ Prophet modeling of the CO₂ flood, Horn Mountain oil field NFB M Sand (985 acres, Sor 32.5%, DP = 0.75)

Year	CO ₂ Inj (Bcf)	Oil Prod (MMbbls)	CO ₂ Prod (Bcf)	Purch CO ₂ (Bcf)	CO ₂ Util (Mcf/bbl)
1	26.3	1.3	0.0	26.3	20.4
2	52.6	3.0	3.8	48.8	16.0
3	78.9	4.5	13.0	65.9	14.8
4	105.2	5.6	24.9	80.3	14.3
5	131.5	6.7	38.4	93.1	13.9
6	157.8	7.7	52.9	104.9	13.6
7	184.1	8.6	68.5	115.6	13.4
8	210.4	9.4	85.1	125.3	13.4
9	236.7	10.1	102.2	134.5	13.4
10	263.0	10.8	119.4	143.6	13.3
11	289.3	11.6	137.0	152.3	13.2
12	315.6	12.3	155.1	160.5	13.1
13	341.9	12.9	173.6	168.3	13.1
14	368.2	13.4	192.6	175.6	13.1
15	394.5	13.9	211.9	182.6	13.1
16	420.8	14.3	231.4	189.3	13.2
17	447.1	14.8	251.1	196.0	13.3
18	473.4	15.2	271.0	202.4	13.3
19	499.7	15.6	290.9	208.8	13.4
20	527.6	16.1	312.3	215.4	13.4

Exhibit 6-6. Oil production, CO₂ injection, and CO₂ production; CO₂ Prophet modeling of the CO₂ flood, Horn Mountain oil field NFB M sand; (985 acres, Sor 32.5%, DP = 0.5)

Year	CO ₂ Inj (Bcf)	Oil Prod (MMbbls)	CO ₂ Prod (Bcf)	Purch CO ₂ (Bcf)	CO ₂ Util (Mcf/bbl)
1	26.3	1.2	0.0	26.3	22.8
2	52.6	2.6	0.1	52.5	20.0
3	78.9	4.4	2.6	76.3	17.5
4	105.2	6.1	8.2	97.0	16.0
5	131.5	7.7	16.2	115.3	15.0
6	157.8	9.2	25.9	131.9	14.3
7	184.1	10.6	37.0	147.1	13.8
8	210.4	11.9	49.3	161.1	13.5
9	236.7	13.2	62.6	174.1	13.2
10	263.0	14.3	76.6	186.4	13.0
11	289.3	15.5	91.2	198.1	12.8
12	315.6	16.5	106.5	209.1	12.7
13	341.9	17.5	122.3	219.6	12.5
14	368.2	18.4	138.7	229.5	12.5
15	394.5	19.3	155.5	239.0	12.4
16	420.8	20.1	172.7	248.1	12.3
17	447.1	20.9	190.0	257.1	12.3
18	473.4	21.8	207.6	265.8	12.2
19	499.7	22.5	225.4	274.3	12.2
20	527.6	23.4	244.6	283.0	12.1

7 COMPARATIVE ANALYSIS OF GEM AND CO₂ PROPHET MODELING OF CO₂ FLOOD, HORN MOUNTAIN OIL FIELD NFB M SAND

Based on the information provided in Section 5 and Section 6, the study found that the CO₂ Prophet Model was able to reasonably represent the performance of the CO₂ flood modeled using the more sophisticated GEM compositional simulator. Exhibit 7-1 provides a comparison of the results for the Horn Mountain oil field NFB M Sand from the two reservoir models. The DP reservoir heterogeneity values of 0.5 to 0.75 used in the CO₂ Prophet Model provide results that bracket the performance of the CO₂ flood in scenarios 1–3 calculated using GEM. Appendix B provides additional data and information comparing annual oil production from the GEM and the CO₂ Prophet models (more details provided in Appendix B).

Exhibit 7-1. Comparative assessments of performance for the Horn Mountain oil field NFB M Sand

Parameter	CO ₂ Flood Performance GEM			CO ₂ Flood Performance CO ₂ Prophet Model	
	Scenario 1	Scenario 2	Scenario 3	DP = 0.75	DP = 0.5
OOIP (MMbbls)	154	154	154	154	154
CO ₂ Injection (Bcf)	526	526	526	528	528
CO ₂ Production (Bcf)	255	268	264	312	245
CO ₂ Storage (Bcf)	271	258	262	215	283
Cumulative Oil Recovery					
MMbbls	19.2	15.5	22.5	16.1	23.4
% of OOIP	12.5%	10.1%	14.6%	10.5%	15.2%
CO₂/Oil Ratio (Mcf/bbl)					
Gross	27.4	33.9	23.4	32.8	22.6
Net	14.1	16.6	11.6	13.4	12.1

In addition to the three scenarios discussed above, the study examined the more capital-intensive Scenario 4, involving drilling three new CO₂ injection wells and shutting in the inactive A6 water injection well. While this scenario provided the largest volume of incremental oil recovery and CO₂ storage, it requires information beyond the data in the Bureau of Ocean Energy Management database and reservoir modeling sophistication beyond the current capabilities of the CO₂ Prophet Model.

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APPENDIX A

This Appendix provides additional data and information on well by well production from the “first-order” history match.

Exhibit A-1. Annual Oil Production by Well vs. History Match -- NFB Horn Mountain (MMbbl)

Year	Well A2		Well A3		Well A4		Total NFB	
	Actual (MMbbl)	History Match (MMbbl)	Actual (MMbbl)	History Match (MMbbl)	Actual (MMbbl)	History Match (MMbbl)	Actual (MMbbl)	History Match (MMbbl)
2003	3.09	3.09	2.55	2.55	3.09	3.09	8.73	8.73
2004	2.50	2.51	3.52	3.53	3.05	3.05	9.07	9.09
2005	2.11	2.11	2.82	2.82	2.49	2.49	7.42	7.42
2006	2.29	2.29	2.66	2.66	2.39	2.39	7.34	7.34
2007	2.10	2.10	1.40	1.40	2.05	2.05	5.54	5.54
2008	2.25	2.26	0.69	0.69	1.70	1.71	4.64	4.66
2009	1.94	1.94	0.55	0.55	1.54	1.54	4.04	4.04
2010	1.30	1.30	0.17	0.17	1.45	1.45	2.92	2.92
2011	0.62	0.62	0.26	0.26	0.94	0.94	1.83	1.83
2012	0.69	0.69	0.18	0.18	1.02	1.02	1.89	1.90
2013	1.06	1.06	0.03	0.03	1.14	1.14	2.22	2.22
2014	1.00	1.00	0.11	0.11	1.18	1.18	2.29	2.29
2015	0.82	0.82	0.10	0.10	1.00	1.00	1.93	1.93
2016	0.78	0.78	0.03	0.03	0.96	0.97	1.77	1.78
2017	0.73	0.73	0.00	0.00	0.89	0.89	1.61	1.61
2018	0.61	0.61	0.00	0.00	0.85	0.85	1.46	1.46
Total	23.89	23.91	15.08	15.09	25.74	25.76	64.71	64.75

Exhibit A-2. Annual Gas Production by Well vs. History Match -- NFB Horn Mountain (Bcf)

Year	Well A2		Well A3		Well A4		Total NFB	
	Actual (MMbbl)	History Match (MMbbl)	Actual (MMbbl)	History Match (MMbbl)	Actual (MMbbl)	History Match (MMbbl)	Actual (MMbbl)	History Match (MMbbl)
2003	2.52	2.48	2.04	2.05	2.61	2.48	7.17	7.01
2004	2.02	2.01	2.80	2.84	2.53	2.45	7.35	7.30
2005	1.65	1.69	2.14	2.27	1.99	2.00	5.78	5.96
2006	1.68	1.84	1.94	2.14	1.83	1.92	5.45	5.90
2007	1.52	1.69	1.12	1.12	1.62	1.64	4.26	4.45
2008	1.54	1.81	0.55	0.56	1.32	1.37	3.42	3.74
2009	1.33	1.56	0.49	0.45	1.19	1.24	3.01	3.24
2010	1.07	1.05	0.13	0.14	1.25	1.16	2.44	2.35
2011	0.50	0.50	0.25	0.21	0.77	0.76	1.52	1.47
2012	0.55	0.56	0.10	0.14	0.81	0.82	1.46	1.52
2013	0.90	0.85	0.00	0.02	0.95	0.91	1.85	1.78
2014	0.82	0.80	0.20	0.09	0.99	0.95	2.01	1.84
2015	0.66	0.66	0.18	0.08	0.83	0.81	1.67	1.55
2016	0.63	0.63	0.03	0.03	0.71	0.78	1.38	1.43
2017	0.51	0.58	0.00	0.00	0.56	0.71	1.07	1.29
2018	0.42	0.49	0.00	0.00	0.72	0.69	1.14	1.18
Total	18.32	19.20	11.98	12.12	20.68	20.69	50.98	52.01

Exhibit A-3. Annual Water Production by Well vs. History Match -- NFB Horn Mountain (MMbbl)

Year	Well A2		Well A3		Well A4		Total NFB	
	Actual (MMbbl)	History Match (MMbbl)	Actual (MMbbl)	History Match (MMbbl)	Actual (MMbbl)	History Match (MMbbl)	Actual (MMbbl)	History Match (MMbbl)
2003	0.00	0.08	0.00	0.07	0.00	0.08	0.01	0.23
2004	0.00	0.06	-	0.09	0.01	0.08	0.01	0.24
2005	0.01	0.05	0.02	0.10	0.08	0.06	0.11	0.22
2006	0.01	0.06	0.32	0.72	0.30	0.06	0.63	0.84
2007	0.06	0.05	0.82	0.78	0.46	0.42	1.34	1.26
2008	0.02	0.06	0.92	0.55	0.61	0.95	1.56	1.56
2009	0.16	0.05	1.18	0.55	0.69	1.21	2.03	1.81
2010	0.34	0.06	0.52	0.20	0.76	1.48	1.62	1.74
2011	0.24	0.09	0.79	0.32	0.64	1.09	1.67	1.50
2012	0.37	0.18	0.84	0.24	0.86	1.28	2.07	1.70
2013	0.63	0.36	0.14	0.04	1.05	1.50	1.82	1.90
2014	0.70	0.50	0.92	0.18	1.19	1.62	2.81	2.31
2015	0.69	0.61	0.92	0.17	1.14	1.43	2.74	2.20
2016	0.81	0.76	0.32	0.06	1.22	1.42	2.35	2.24
2017	0.83	0.90	0.00	0.00	1.10	1.36	1.93	2.26
2018	0.89	0.92	0.00	0.00	1.17	1.36	2.06	2.29
Total	5.77	4.81	7.71	4.07	11.28	15.40	24.76	24.28

APPENDIX B

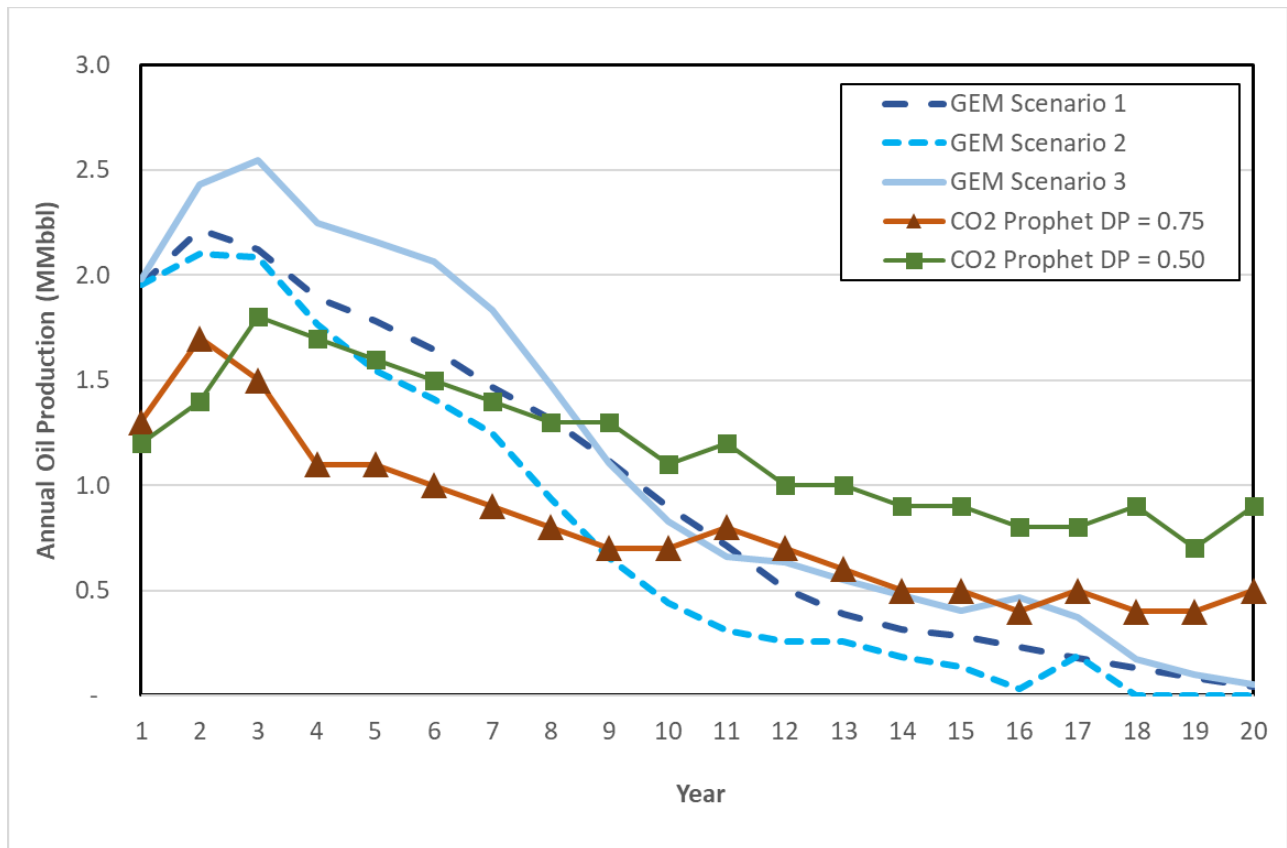
This Appendix provides additional data and information comparing annual oil production from the GEM and the CO₂ Prophet models.

Exhibit B-1. Annual Incremental Oil Production -- GEM vs. CO₂ Prophet (MMbbl)*

Year	GEM Model			CO ₂ Prophet Model	
	Scenario 1	Scenario 2	Scenario 3	DP = 0.75	DP = 0.50
1	2.0	2.0	2.0	1.3	1.2
2	2.2	2.1	2.4	1.7	1.4
3	2.1	2.1	2.5	1.5	1.8
4	1.9	1.8	2.2	1.1	1.7
5	1.8	1.5	2.2	1.1	1.6
6	1.6	1.4	2.1	1.0	1.5
7	1.5	1.2	1.8	0.9	1.4
8	1.3	0.9	1.5	0.8	1.3
9	1.1	0.7	1.1	0.7	1.3
10	0.9	0.4	0.8	0.7	1.1
11	0.7	0.3	0.7	0.8	1.2
12	0.5	0.3	0.6	0.7	1.0
13	0.4	0.3	0.6	0.6	1.0
14	0.3	0.2	0.5	0.5	0.9
15	0.3	0.1	0.4	0.5	0.9
16	0.2	0.0	0.5	0.4	0.8
17	0.2	0.2	0.4	0.5	0.8
18	0.1	-	0.2	0.4	0.9
19	0.1	-	0.1	0.4	0.7
20	0.0	-	0.1	0.5	0.9
Total	19.3	15.5	22.6	16.1	23.4

*Totals may not add due to rounding

Exhibit B-2. Chart of Annual Incremental Oil Production -- GEM vs. CO₂ Prophet (MMbbl)





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